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Stable Mechanical Design of Coherent X-ray Scattering Beamline at Taiwan Photon Source

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Abstract **-**The Coherent X-ray Scattering (CXS) beamline is one of the phase-I beamlines at Taiwan Photon Source. This beamline is mainly designed for advanced experimental techniques of X-ray photon correlation spectroscopy, coherent diffraction imaging, and small-angle X-ray scattering with operating energy of 5 - 20 keV. To optimize the wide applications of the advanced CXS techniques, the beam sizes in horizontal and vertical directions at sample are adjustable within 1 - 10 μm by controlling focusing mirrors, secondary source slits, and other optics in the CXS beamline. Consequently, the optical components for defining beam sizes are very critical for beamline performance, and required to be precisely designed with high stability. The mechanical resolution and accuracy of the components should reach submicron level to sustain the advanced techniques at the CXS beamline. Moreover, ambient vibration and temperature fluctuation at the CXS beamline are also important issues for stability of components. To minimize the influence of environment uncertainties, a precise temperature controlling system is designed to be adopted on all critical components. Recently, the precise temperature controlling system and stable design of slits components have been accomplished and commissioning. The overall design concept and mechanical specification for slits components and precise temperature controlling system will be reported in this paper.

Keywords**:** Coherent X-ray Scattering (CXS), X-ray photon correlation spectroscopy, small-angle X-ray scatting, secondary source slits, precise temperature controlling system

1. Introduction

The Coherent X-ray Scattering (CXS) beamline at Taiwan Photon Source (TPS) needs very high stability for its wide applications, and the definition of beam size becomes more critical. To reach the specification of slits, specific mechanical criteria is applied into slits system. The transmission of vibration from ground and connected pipes is prevented by using granite plinth on epoxy grout base and de-coupled design, and the thermal effect is reduced by controlling environmental temperature precisely. The precise temperature controlling system has been developed and initially tested by the engineers of utility group in National Synchrotron Radiation Research Center (NSRRC). The testing results are described in a paper by Z. D. Tsai et al (2014). The fluctuation of controlled temperature can reach ±0.01 ℃ by exactly tuning flow rates of chilled and hot water to coils of heat exchangers. Mono beam slits system, secondary source slits system, and precise temperature controlling system are described in the next sections respectively.

2. Layout of the CXS Beamline at TPS

The CXS beamline at TPS can provide a highly coherent beam by using 3 m-long and 2 m-long in-vacuum undulators, and the operating energy is designed within 5-20 keV. Considering the application and safety protection, this beamline consists of several important components. Fig. 1 shows the view of whole beam. From upstream to downstream, the components of beamline are mask, filter, bremsstrahlung collimator, double crystal monochromator (DCM), bremsstrahlung stopper, integrated system for slits and beam monitoring components, 1st horizontal focusing mirror (HFM1), secondary source slits, K-B mirrors, sample stage, and area detector respectively. Two sets of mono beam slits in integrated system for slits and beam monitoring components are located in the entrances of HFM1 and K-B Mirrors, and they are used to control the beam sizes in horizontal and vertical directions in focusing positions. Secondary source slits are used to control the beam size at sample between 1 μm and 10 μm in horizontal direction.

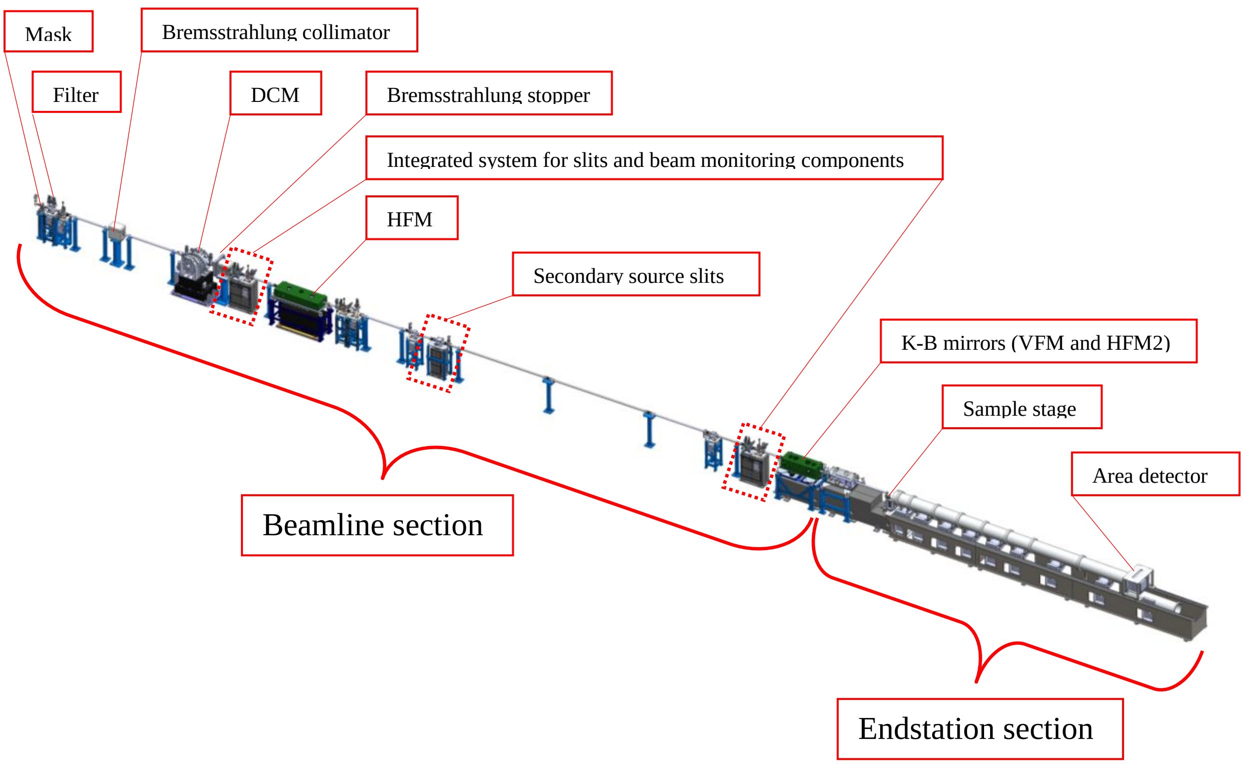

Fig. 1. View of the whole CXS beamline

3. Standard Slits Components

Integrated system for slits and beam monitoring components, which is shown in Fig. 2, consists of quadrant beam positioning monitor (QBPM), mono beam slits, and mono beam screen. QBPM and mono beam screen are used for beam monitoring. All the components are installed on the granite plinth, which stands on the epoxy grout base. Granite has higher damping capacity to minimize effect of vibration, and so does epoxy grout. Mono beam slits uses four tungsten blades to define beam sizes, and they are controlled by stepper motors. Application of zero beam is possible due to the gap between which blade.

Film of single crystal was bonded to the tapered side of blade for the scatterless application of X-ray, which criteria is described in a paper by Y. Li et al (2008). Position accuracy and resolution of mono beam slits have been verified to be 1 μm and 0.1 μm respectively. There are feedthroughs to connect in-vacuum metal blades and in-air amplifiers for signal acquisition of current, and they can be also used for monitor of beam position.

Fig. 3 shows the whole view of secondary source slits system and detailed view of slits and holder. Secondary source slits are more critical than mono beam slits, so the specification should be more severe. Similarly, holder of slits is installed on the granite plinth, which stands on the epoxy grout base. Specifically, de-coupled design is applied to isolate transporting of vibration from connected beam pipes to holder. Vacuum chamber is fixed on the structural stands and connected to holder with welded bellows. Furthermore, precise temperature controlling system will be adopted to minimize the thermal effect on structural stability. Not only granite has higher damping capacity, but also it has higher thermal inertia, which can make controlled areas more thermally stable. Piazo stages will be used to control four tungsten blades and installed on holder. Invar alloy will be used as material of holder for its very low property of thermal expansion, and it can also reduce thermal effect on mechanical structure. To reduce scattering effect, each blade also has bonded film of single crystal on its tapered side. Position accuracy and resolution are expected to 0.2 μm and 0.006 μm respectively, but still some advanced tests need to be performed in the future. Other specifications of mono beam slits and secondary source slits are listed in Table. 1 and Table. 2 respectively.

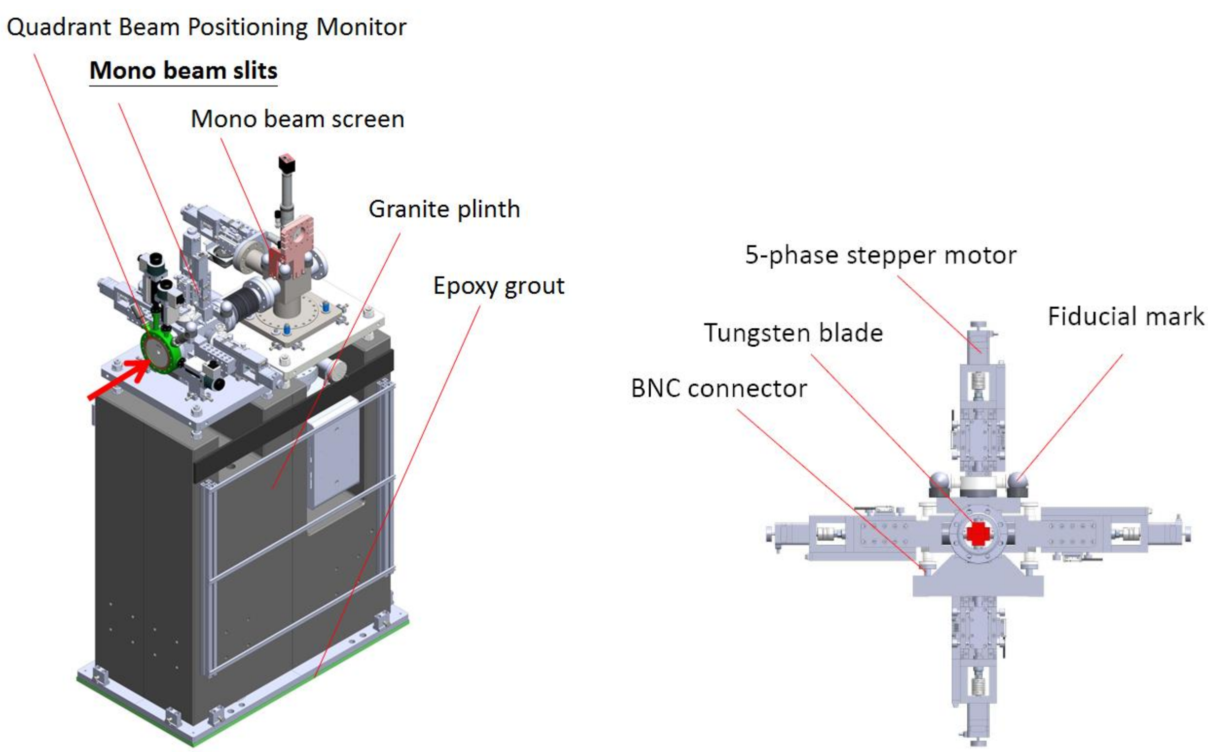

Fig. 2. (a)Integrated system for Slits and beam monitoring components (b)Detailed view of Mono beam slits.

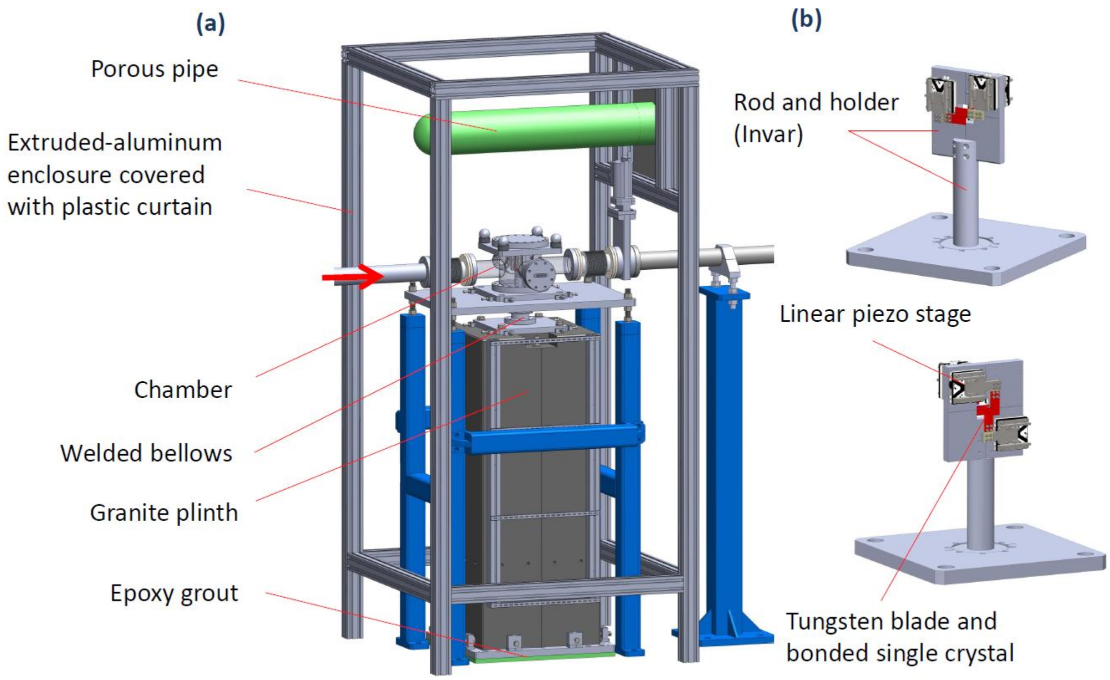

Fig. 3. (a)Secondary source slits inside extruded aluminum enclosure (b)Detailed view of slits and holder

Table. 1. Specification of mono beam slits

Maximum aperture	10 mm (H) × 10 mm (V)
Movement range (each blade)	±5 mm
Position resolution	≤ 0.1 µm
Position repeatability (closed-loop)	≤ 0.5 µm
Position accuracy (closed-loop)	≤ 1 µm
Material	Tungsten alloy GaAs single crystal
Straightness	1 µm over 10 mm
Surface finish on beam intercepting face	≤ 0.1 µm Ra
Parallelism of slit blades	≤ 20 µm

Table. 2. Specification of secondary source slits

Maximum aperture	13 mm (H) × 13 mm (V)
Movement range (each blade)	±6.5 mm
Position resolution	≤ 0.006 µm
Position repeatability (closed-loop)	≤ 0.018 µm
Position accuracy (closed-loop)	≤ 0.2 µm
Material	Tungsten carbide GaAs single crystal
Surface finish on beam intercepting face	≤ 0.1 µm Ra
Parallelism of slit blades	≤ 10 µm

4. Precise Temperature Controlling System

The compact-type air handling unit (AHU) will be used in precise temperature controlling system. All devices for air conditioning, such as proportional valves with high precision, coil-type heat exchangers, sensors of temperature, variable frequency drive of fan, programmable automation controller, and so on, are installed inside AHU. Controlled areas have to be thermally isolated, so extruded-aluminum enclosures covered with plastic curtain are used. Porous pipes are used to supply stable air flow due to their fabric surface. According to the testing results performed by engineers in utility group, the temperature of supplied air can be highly stable with fluctuation within ±0.01 ℃. The set-up of temperature controlling areas contains three areas shown in Fig. 4. The AHU generates air with highly precise temperature to every region through thermally insulated air pipes. Flow rate of air to each region needs to be controlled by adjusting the dampers installed on the transport pipes. Result of flow simulation is shown in Fig. 5, which indicates variation of temperature with time when air change rates are 30 ACH (Air changes per hour) and 60 ACH. Temperature of supplied air set to 25 ℃, and monitored point p2 is located near heat source in space. The heat source generates power of 80 W and stops heating after 300 seconds. It is found that temperature with 60 ACH becomes stable more fast than that with 30 ACH. Therefore air change rate of precise temperature controlling system will be set to 60 ACH for removing heat from hot devices more efficiently.

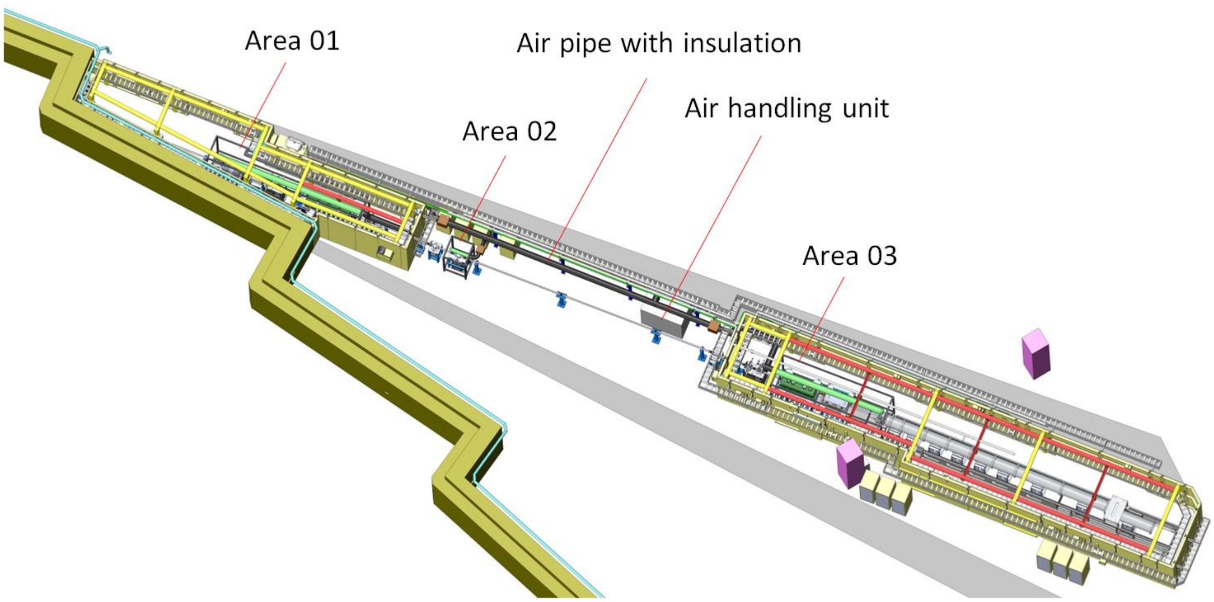

Fig. 4. Schematic of precise temperature controlling areas

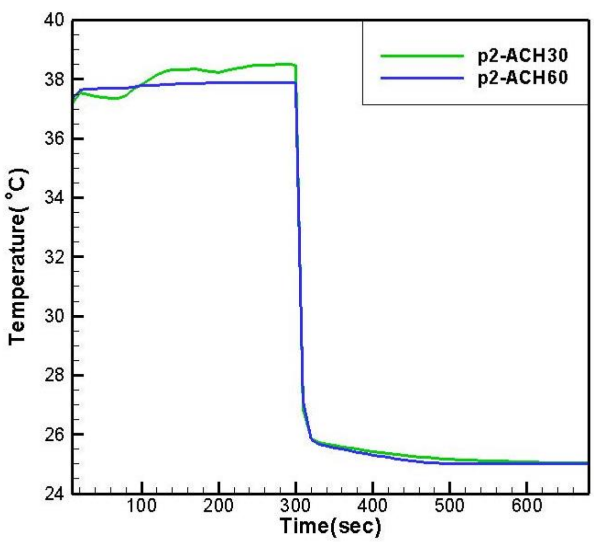

Fig. 5. Result of flow simulation

5. Conclusion

The slits components and precise temperature controlling system for CXS beamline have been designed, fabricated, assembled, and preliminary tested. Issues involving mechanical instability have been considered, and preventive methods will also be adopted to every slits system for optimizing their performance. However, some issues still need to be verified. Firstly, secondary source slits need advanced tests to verify position accuracy. Secondly, effect of heat generated from electronic components, such as ionization gauges and stepper motors, has not been confirmed clearly. Evaluation of heat sources using flow simulation and particular tests needs to be on going to assure the set-up and parameters of precise temperature controlling system.

References

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